

# **LIGHT EMITTING DIODE STRUCTURE AND MANUFACTURE METHOD THEREOF**

## **BACKGROUND OF THE INVENTION**

### **1. Field of the Invention**

**[0001]** The present invention relates to light-emitting diodes (LEDs) structures, and more particularly, to an LED structure containing a p-type quantum-spot epitaxial layer grown on a p-type GaN layer. The present invention also relates to a manufacture method for the LED.

### **2. The Prior Art**

**[0002]** Because the refractive index ( $n$ ) of gallium nitride (GaN) semiconductor as an LED material is 2.3 approximately, far different from that of air ( $n=1$ ), a small critical angle of total reflection about  $25^\circ$  is resulted to block almost all the incident rays emitted from a light-emitting layer of LED.

**[0003]** For improvement, a known method according to IEEE Transactions on Electron Devices, 47(7), 1492, 2000 was presented to coarsen a semiconductor surface, particularly an epitaxy surface to raise the scattering and refracting probability of incident light usually by way of etching. US Patent No. 5,040,044 discloses a chemical etching process for coarsening a light-emitting element to improve light emitting efficiency. Besides, there are other similitudes, such as US Patent Nos. 5,429,954 and 5,898,192. However, the mentioned processing method is applicable only to the red-light LED, not to GaN-based materials which is especially weak in resistance against acids/alkalis, and it is relatively difficult to control a wet etching process while a dry etching process is liable to spoil the epitaxial layer and cause an increment of impedance, particularly in the case of a P-type GaN layer, to thereby affect the current distribution and degrade the light-emitting efficiency. In addition, because the deposited p-type GaN layer is extremely thin (only 0.1-0.3  $\mu\text{m}$ ), the light-emitting layer could be impaired occasionally by a direct coarsening to result in a smaller light-emitting area. For promoting permeability, the transparent electrode on a GaN LED should be made as thinner as possible (about 10 nm) so that a direct coarsening job might destroy the transparent thin electrode or makes it

discrete to badly affect the current distribution and light-emitting efficiency. On the other hand, though the dry etching process is applicable to a p-type GaN layer having a sufficient thickness, the current distribution and light-emitting efficiency is nevertheless deteriorated to hence set the coarsening process in a dilemma.

### **SUMMARY OF THE INVENTION**

**[0004]** In view of the foregoing problems, the present invention is aimed to coarsen the surface of GaN layer of a light-emitting element by way of growing an epitaxial layer for enhancing light-emitting efficiency significantly.

**[0005]** Therefore, a primary object of the present invention is to grow a p-type quantum-dot epitaxial layer on a p-type GaN layer to simplify the prior coarsening process of a conventional LED.

**[0006]** Another object of the present invention is to change the path of light emitted from an InGaN multiple-quantum-well structural layer by availing the scattering effect of a coarsened p-type quantum-dot epitaxial layer to hence decrease the probability of total reflection and heighten the light-emitting efficiency.

**[0007]** For more detailed information regarding advantages or features of the present invention, at least an example of preferred embodiment will be described below with reference to the annexed drawings.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0008]** The related drawings in connection with the detailed description of the present invention to be made later are described briefly as follows, in which:

**[0009]** Figure 1 is a schematic view showing the structure of LED according to an embodiment of the present invention; and

**[0010]** Figure 2 shows a manufacture flowchart of LED according to the embodiment of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

**[0011]** Figure 1 is a schematic view showing the structure of LED according to an embodiment of the present invention. A sapphire substrate **101**, which is made of SiC, Si, GaAs, LiAlO<sub>2</sub>, LiGaO<sub>2</sub>, or AlN, is put in a MOCVD (Metal Organic Chemical Vapor Deposition) system.

**[0012]** A GaN buffer layer **102** of 20-50 nm thick is formed firstly on the substrate **101** in 500-600°C vapor, then an LED structural layer **103** on the buffer layer **102**. The LED structural layer **103** comprises an n-type GaN layer **1030**, a multiple-quantum-well structural layer **1032**, a p-type GaAlN layer **1034**, and a p-type GaN layer **1036**, in which the n-type GaN layer **1030** grown on the buffer layer **102** is a GaN-based compound of group III-V.

**[0013]** The n-type GaN layer **1030** is a 1-2μm thick Si-impurity-doped layer made in GaN-based compound semiconductor and grown by raising temperature of the substrate to 1000-1200°C. The test piece is then drawn out and dipped in the MOCVD system and the substrate **101** is heated to 700-900°C to form the multiple-quantum-well structural layer (InGaN) **1032** as a light-emitting layer, which is overlapped by the p-type GaAlN layer (Mg-doped) **1034**, the p-type GaN layer (Mg-doped) **1036**, and a final Mg-doped p-type quantum-dot epitaxial layer **107**. The p-type quantum-dot epitaxial layer **107** is substantially a 10Å-degree coarse-grained Al<sub>x</sub>Ga<sub>(1-x-y)</sub>In<sub>y</sub>N thin film, where  $0 \leq x, y < 1, 0 \leq x+y < 1$ . By means of the foregoing process, an LED epitaxial chip is completed.

**[0014]** The epitaxial chip then undergoes an ICP-RIE (inductively coupled plasma-reactive ion etching) dry etching process for removing part of the p-type quantum-dot epitaxial layer **107**, p-type GaN layer **1036**, p-type GaAlN layer **1034**, and InGaN multiple-quantum-well structural layer **1032** in order to expose the surface of the n-type GaN layer **1030**. Then, Ni/AuBe is laid on the surface of the p-type quantum-dot epitaxial layer **107** and electrically connected therewith to serve for a p-type ohmic contact electrode **108**, while Ti/Pt/Al/Ti/Au is laid on the surface of the n-type GaN layer **1030** and electrically connected therewith to serve for an n-type ohmic contact electrode **109** to thereby form a grain structure to which a forward bias may be applied.

**[0015]** Figure 2 shows a manufacture flowchart of LED according to the embodiment of the present invention. As shown in Figure 2, a manufacture method of LED of the present invention comprises a step 210 for growing a buffer layer, a step 203 for growing an LED structural layer **103**, a step 205 for growing a quantum-dot epitaxial layer **107**, and a step 207 for forming an electrode **108/109**.

**[0016]** In step 201, a sapphire substrate **101** is immersed in a MOCVD system and heated to 500-600°C to form a GaN buffer layer **102** of 20-50 nm thick. In step 203, the substrate **101** is heated to 1000-1200°C to form a Si-impurity-doped n-type GaN layer **1030** of 1-2μm thick, and then, the test piece is taken out and masked in stripes on its surface by a photolithography process, then etched by a dry etching process in order to obtain a grid pattern. The grid-pattern attached test piece is immersed in the MOCVD again and heated to 700-900°C at this time to grow an InGaN multiple-quantum-well structural layer **1032** for serving as a light-emitting layer, on which there comes an Mg-doped p-type GaAlN layer **1034**, and an Mg-doped p-type GaN layer **1036** follows. In step 205, an Mg-doped p-type quantum-dot epitaxial layer **107** is grown on the p-type GaN layer **1036** to complete an LED epitaxial chip.

**[0017]** Finally, in step 207, the LED epitaxial chip is supposed to undergo an ICP-RIE (inductively coupled plasma-reactive ion etching) dry etching process for removing part of the p-type quantum-dot epitaxial layer **107**, p-type GaN layer **1036**, p-type GaAlN layer **1034**, and InGaN multiple-quantum-well structural layer **1032** so as to expose the surface of the n-type GaN layer **1030**. Then, Ni/AuBe is laid on the surface of the p-type quantum-dot epitaxial layer **107** and electrically connected therewith to serve for a p-type ohmic contact electrode **108**, while Ti/Pt/Al/Ti/Au is formed on the surface of the n-type GaN layer **1030** and electrically connected therewith to serve for an n-type ohmic contact electrode **109** to thereby form a grain structure to which a forward bias may be applied as mentioned above.

**[0018]** In the above described, a preferred embodiment has been described in detail with reference to the drawings annexed, and it is apparent that numerous changes or modifications may be made without departing from the true spirit and scope thereof, as set forth in the claims below.